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IDENTIFICATION OF ASBESTOS FOR REGION V

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PREPARED FOR
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Analysis results of 20 coded filter samples supplied by the Minnesota State Pollution Agency are presented. The filters were examined for asbestos using electron microscope techniques. Data are presented in summary tables and in tables giving the detailed results for each individual sample.

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"Identification of Asbestos for Region V"

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FOREWORD

This report details the analysis results of twenty coded filter samples supplied by Minnesota State Pollution Agency. The filters were examined for asbestos using electron microscope techniques.

The work was performed under EPA Contract No. 68-01-3163 Task 6. Mr. George Hurt of the Environmental Protection Agency, Region V was the Project Officer. Dr. Colin F. Harwood of IIT Research Institute served as Project Leader assisted by two electron microscopists, Dr. Anant Samudra and George Yamate. The project was administered from the Fine Particles Section with Mr. John D. Stockham, Manager.

Respectfully submitted,
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IDENTIFICATION OF ASBESTOS FOR REGION V

1. INTRODUCTION

Twenty membrane filter samples were forwarded to IIT Research Institute from the Minneapolis State Pollution Agency. The samples were examined for fiber concentration using the technique outlined below. The results of the analysis are given in summary tables and in tables giving the detailed results for each individual sample. Four blank samples were also examined. Thus, the total number of samples examined was twenty four.

2. SAMPLE PREPARATION

The coded filter samples were received as wedge shaped "pie" portions of a 47 mm diameter Millipore filter. Each sample was prepared for examination in the following manner.

1. A carbon film was vacuum deposited on the collection side of the filter.
2. A 3 mm section was punched from the mid-section of the carbon-coated filter.
3. The 3 mm section was placed deposit side up on to a carbon-coated, nickel, electron microscope grid.
4. The grid and filter portion were placed into a "cold finger" washer with acetone as the solvent. The grid was placed on a stainless steel wire mesh which in turn rested on the cold finger.
5. Gentle acetone washing was continued for about five hours.
6. When the filter was dissolved away the grids containing the particles were stored in grid specimen holders prior to examination.
7. Four blank samples supplied by Minnesota State Pollution Agency were prepared in an identical manner.

3. GRID ANALYSIS

A JEOL 100C transmission, scanning microscope with X-ray attachment was used for fiber counting and fiber identification. The integrity of the carbon substrate was first established at low magnification (about 1000X). A grid opening was then randomly selected. The grid opening was scanned at 20,000 times magnification and 100KV accelerating voltage. The length and breadth of all the particles having substantially parallel sides and a minimum aspect ratio 3:1 were measured on the fluorescent screen one edge of which is graduated in millimeters.

A total of 100 fibers were to be measured unless fewer than 100 fibers were found in two complete grid openings. Actually, many of the filters were very slightly loaded and up to 6 grid openings were scanned with a consequent increase in effort and time.

Approximately 10% of the fibers (randomly selected) were examined by selected-area diffraction and by X-ray chemistry. In many instances,because of the low number of fibers found the number of fibers tested reached 50 or 100%, (see the following tables). The selected-area, electron diffraction pattern were classified into groups depending on the pattern obtained. The groups were amphibole, non-amphibole, ambiguous or non-crystalline. To obtain the X-ray analysis the electron beam was reduced in size (spot size 2) and focussed on the fiber and then stigmated along the length of the fiber. The X-ray signal was collected for 30 seconds. The principal peaks in the spectrum were noted.

The data obtained on each of the twenty samples and four blanks is summarized in Table 1 and 2. Full details of the analysis of each sample are given in Appendix A.

4. TIME AND COST

Exact figures for the time and cost involved in performing Task 6 cannot be given until the final cost figures are known. It is estimated that 500 man hours will be expended at a total cost of $14,167 exclusive of fee.

Appendix A

TABULATION OF RESULTS

Note: In the following tables, those fibers noted as CG are fibers which are indicated as possible amphibole fibers. Those marked +CG are positively indicated as amphibole fibers. Again, note that under the terms of the contract, only a minimum of 10% of the fibers were checked by both electron and X-ray probe analysis.

Table 1
SUMMARY OF RESULTS

Sample Code	Area Examined x 10^{-6} cm^2	Total No. of Fibers	Definite Cummingtonite Grunerite Fibers	Possible Cummingtonite Grunerite Fibers
62 xx	320	30	N	3
64 xx	384	43	2	10
65 xx Blank	256	3	N	N
66 xx	192	13	N	1
68 xx	320	22	N	4
113 xx Blank	320	4	N	N
114 xx	512	10	1	1
116 xx	320	41	7	9
118 xx	256	17	4	2
120 xx	512	6	1	3
184 xx	320	30	N	1
186 xx	256	59	2	2
188 xx	256	78	6	14
190 xx	320	15	N	4
199 xx Blank	448	10	N	N
200 xx	704	54	4	5
222 xx	384	9	N	N
236 xx	448	10	N	N
250 xx	256	62	2	3
305 xx Blank	384	7	N	N
306 xx	256	23	5	4
308 xx	320	25	2	3
310 xx	384	12	5	1
312 xx	448	34	2	7

N - Non-detected in the area scanned

Table 2

SIZE DISTRIBUTION OF FIBERS

Sample Code	Size Category of Fibers (μm)								Number Of Fibers Observed
	<0.5		0.5-<2.0		2-<5.0		≥5.0		
	No.	%	No.	%	No.	%	No.	%	
62 xx	3	10	16	53	6	20	5	17	30
64 xx	8	19	23	53	6	14	6	14	43
Blank 65 xx	2	67	1	33	-	-	-	-	3
66 xx	1	8	8	62	4	30	-	-	13
68 xx	3	14	14	64	5	22	-	-	22
Blank 113 xx	-	-	3	75	1	25	-	-	4
114 xx	1	10	6	60	1	10	2	20	10
116 xx	8	20	24	58	6	15	3	7	41
118 xx	3	18	9	53	3	18	2	11	17
120 xx	3	50	2	33	1	17	-	-	6
184 xx	5	17	20	66	5	17	-	-	30
186 xx	3	5	35	59	19	32	2	3	59
188 xx	13	17	38	49	23	29	4	5	78
190 xx	1	7	9	60	4	27	1	7	15
Blank 199 xx	2	20	7	70	1	10	-	-	10
200 xx	6	11	44	82	3	5	1	2	54
222 xx	5	56	4	-	-	-	-	-	9
236 xx	7	70	3	30	-	-	-	-	10
250 xx	11	18	45	73	5	8	1	1	62
Blank 305 xx	5	71	2	29	-	-	-	-	7
306 xx	-	-	17	74	6	26	-	-	23
308 xx	10	40	12	48	3	12	-	-	25
310 xx	-	-	10	83	2	17	-	-	12
312 xx	11	32	15	44	8	29	-	-	34
Av. %		24		56		16		4	

Table A1

SAMPLE 62 xx

Grid Opening	Fiber No.	Fiber Width, μm	Fiber Length, μm	Diffraction Pattern: Amphibole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambiguous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#1	1	0.05	0.25				✓		
	2	0.25	1.56				✓		
	3	0.25	1.68			✓		Si only	
	4	0.31	2.50		✓			No significant peaks	
	5	0.19	0.75						
	6	0.43	1.37						
	7	0.31	1.12						
#2	8	0.19	1.12				✓		
	9	0.25	1.12			✓		Mg, Si, Ca, Fe	CG
	10	0.31	0.94		✓			S, Ca	
	11	0.31	1.31			✓		Mg, Si, Ca, Fe	CG
#3	12	0.25	4.37				✓		
	13	0.19	3.12				✓		
	14	0.19	0.81			✓		Si, Ca, Fe	CG
	15	0.12	0.62				✓		
	16	0.50	6.25		✓			S, Ca	
	17	1.00	10.00					S, Ca	
	18	1.25	3.75					S, Ca	
	19	1.00	7.50					S, Ca	
	20	0.62	8.75					S, Ca	
	21	0.62	5.62					S, Ca	
	22	0.37	2.50					S, Ca	
	23	0.06	0.37		✓			No significant peaks	
	24	0.09	0.50		✓			No significant peaks	
#5	25	0.09	0.43			✓		Ca, S only	
	26	0.09	0.50			✓		Ca, S, Fe, weak peaks	
	27	0.43	3.43			✓		Ca, S only	
	28	0.12	0.50		✓			Fe, Ca, S, Si	
	29	0.09	0.75		✓			Si, K, S, Al, Fe	
	30	0.37	1.25		✓			Si, Al, Fe	

Table A2

SAMPLE 64 xx

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	1	0.19	1.56				✓	Ca, S	
	2	0.19	1.25				✓	Ca, S, Si	
	3	0.12	1.25				✓	Ca, S	
	4	0.03	0.37				✓	Si, S	
	5	0.06	1.25			✓		Si, Fe	CG
	6	0.75	12.50			✓		Ca, S	
	7	0.25	10.00					Ca, S	
	8	1.25	13.70	✓				Ca, S	
	9	0.25	2.18	✓				Ca, S, Fe, Si, Mg, Al	+CG
#2	10	0.78	4.29			✓			
	11	0.10	0.50			✓		Mg, Si, Fe	CG
	12	0.12	0.62			✓		Mg, Si, Fe	CG
	13	0.12	0.37			✓		Mg, Si, Fe	CG
	14	0.12	0.62			✓		Mg, Si, Fe	CG
	15	0.10	0.45			✓		Mg, Si, Fe	CG
	16	0.15	0.50			✓		Mg, Si, Fe	CG
	17	0.62	1.88		✓			P, S only	
	18	0.12	0.43			✓		Si, S, Ca, Fe	CG
	19	0.06	0.25						
	20	0.31	1.25						
#3	21	0.19	1.00			✓		Mg, Si, Fe	CG
	22	0.19	0.62			✓		P, Ca	
	23	0.06	0.43						
	24	0.50	2.31			✓		Mg, Si, Fe	CG
	25	0.12	0.37					Si only	
	26	2.00	7.00					S, Ca	
	27	2.00	6.00					S, Ca	
	28	0.50	1.88			✓			
	29	0.50	2.62						
#4	30	0.25	1.88						
	31	0.12	1.25						
	32	0.12	1.12						
	33	0.62	2.82						
	34	0.62	2.82	✓				Mg, Si, Fe	+CG
#5	NO FIBERS								
#6	35	0.15	0.78		✓			Ca, S	
	36	0.23	1.95		✓				

SAMPLE 64 xx (Continued)

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#6 (cont.)	37	0.23	1.56		✓			Ca, S	
	38	0.15	1.17					Ca, S	
	39	1.56	5.08		✓			Fe, Si, Mg, Ca, Mn	
	40	0.06	0.31						
	41	0.37	1.56						
	42	0.31	1.88						
	43	0.12	1.88						

Table A3

SAMPLE 65 xx Blank

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	NO FIBERS								
#2	NO FIBERS								
#3	NO FIBERS								
#4	1	0.03	0.50		✓				
	2	0.05	0.20		✓				
	3	0.04	0.15		✓				

Table A4

SAMPLE 66 xx

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	1	0.25	1.25			✓		Mg, Si, Ca, Mn, Fe	CG
	2	0.31	2.19					S, Ca	
	3	0.19	0.94		✓			S, Ca	
	4	0.31	1.68					S, Ca	
	5	0.31	2.00					S, Ca	
	6	0.31	0.94					S, Ca	
#2	7	0.31	2.62		✓			S, Ca, weak peaks	
	8	0.25	2.00		✓			S, Ca, weak peaks	
	9	0.12	1.06		✓			No significant peaks	
	10	0.12	1.25				✓		
#3	11	0.07	0.50			✓		No significant peaks	
	12	0.05	0.45				✓		
	13	0.07	0.70				✓		

Table A5

SAMPLE 68 xx

Grid Opening	Fiber No.	Fiber Width, μm	Fiber Length, μm	Diffraction Pattern: Amphibole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambiguous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#1	1	0.19	0.62		✓			Fe only	
	2	0.15	2.37			✓		Si, Fe, Mg	CG
	3	0.06	0.25			✓		Fe, Si, Mg	CG
	4	0.09	0.62			✓		Si, Fe, Mg	CG
	5	0.06	0.43		✓			Ca only	
	6	0.12	0.62		✓			Ca, S only	
	7	0.19	0.75		✓			Si, Al	
	8	0.12	2.50		✓			No significant peaks.	
	9	0.19	1.25		✓			Too close to grid bar for analysis.	
#2	NO FIBERS								
#3	10	0.19	3.12			✓		Si, Fe, Mg	CG
	11	0.31	2.19			✓		Ca, S	
	12	0.25	1.56			✓		Ca, S	
	13	0.19	1.25			✓		Ca, S	
	14	0.25	1.88			✓		Ca, S	
	15	0.19	1.25			✓		Ca, S	
	16	0.25	1.88		✓			Si, Al, K, Fe, small peaks	
#4	17	0.15	1.25		✓			Si only	
	18	0.12	2.24		✓			S, Ca, small peaks	
	19	0.06	0.25		✓			Si, Fe	
	20	0.09	0.50			✓		S, Ca	
#5	21	0.12	0.94		✓			Ca, S	
	22	0.19	0.75		✓			Ca, S only	

Table A6

SAMPLE 113 xx Blank

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	NO FIBERS								
#2	NO FIBERS								
#3	1	0.25	1.88				✓		
	2	0.25	2.50				✓		
#4	3	0.19	1.25						
	4	0.19	0.88						
#5	NO FIBERS								

Table A7

SAMPLE 114 xx

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	NO FIBERS								
#2	1	0.50	3.44	✓				Mg, Si, Ca, Fe	+CG
#3	2	0.12	0.75			✓		Mg, Si, Ca, Fe	CG
#4	NO FIBERS								
#5	3	1.87	5.87			✓		Ti only	
#6	4	0.94	2.81	(POSSIBLY A BUNCH)		✓			
	5	0.06	0.94			✓			
	6	0.06	0.75			✓			
	7	BUNDLE				✓		No significant peaks	
	8	0.25	1.12	✓				No significant peaks	
#7	NO FIBERS								
#8	9	BUNCH OF 13 FIBERS.			CRYSTALLINE			No significant peaks	
	10	0.05	0.37		✓			No significant peaks	

Table A8

SAMPLE 116 xx

Grid Opening	Fiber No.	Fiber Width, μm	Fiber Length, μm	Diffraction Pattern: Amphibole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambiguous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#1	1	0.19	3.45			✓		Mg, Si, Fe	CG
	2	0.38	15.40			✓		Mostly Si	
	3	0.38	7.70			✓		Mostly Si	
	4	0.38	1.15			✓		Si only	
	5	0.76	11.55			✓			
	6	0.12	1.25		✓				
#2	7	0.25	1.25	✓				Fe, Si, Mg, Ca	+CG
	8	0.31	1.56	✓				Fe, Si, Mg, Ca	+CG
	9	0.06	0.62						
	10	0.19	1.87		✓				
#3	11	1.87	5.62	✓				Mg, Si, Fe	+CG
	12	0.19	1.25	✓				Si, Fe	+CG
	13	0.09	1.25			✓			
	14	0.12	1.25			✓			
	15	0.12	0.50			✓			
	16	0.01	0.22						
	17	0.04	0.55						
	18	0.03	0.17						
	19	0.12	0.94		✓				
#4	20	0.02	0.16						
	21	0.02	0.16						
	22	0.02	0.10						
	23	0.04	0.62						
	24	0.05	0.20		✓				
	25	0.07	0.62						
	26	0.10	0.50			✓		Mg, Si, Fe	CG
	27	0.10	0.62			✓		Mg, Si, Fe	CG
	28	0.44	5.00	✓				Mg, Si, Fe	+CG
	29	0.12	0.94						
	30	0.19	0.94						
	31	0.75	3.13			✓		Mg, Si, Fe	CG
	32	0.12	0.94			✓		Mg, Si, Fe	CG
	33	0.19	0.75			✓		Mg, Si, Fe	CG
#5	34	0.22	1.25			✓		Mg, Si, Fe	CG
	35	0.06	0.31			✓		Mg, Si, Fe	CG
	36	0.12	0.50						
	37	0.19	0.94			✓		Fe only	
	38	0.09	0.75			✓		Mg, Si, Fe	CG
	39	0.19	2.50		✓			Mg, Si, Fe, Ca	

SAMPLE 116 xx (Continued)

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#5 (cont.)	40	0.94	3.12	✓				Mg, Si, Fe	+CG
	41	0.09	0.31	✓				Mg, Si, Fe	+CG

Table A9

SAMPLE 118 xx

Grid Opening	Fiber No.	Fiber Width, μm	Fiber Length, μm	Diffraction Pattern: Amphi-bole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambi-guous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#1	1	0.06	0.62			✓		Ca, S	
	2	0.12	0.87					Ca, S	
	3	0.75	2.87	✓				Si, Fe, Mg	+CG
	4	A BUNDLE			✓			Ca only	
#2	5	0.31	3.12					Si, Fe, Mg	CG
	6	0.03	0.25						
#3	7	0.06	0.94	✓					CG
	8	0.15	1.00	✓				Si, Fe, Mg	+CG
	9	0.06	0.25						
#4	10	0.19	1.25						
	11	0.12	1.25						
	12	0.09	1.25						
	13	0.06	0.37						
	14	0.31	1.56						
	15	A BUNDLE						Ca, S, Si	
	16	0.25	0.94	✓				Si, Fe, Mg	+CG
	17	0.12	2.50	✓				Si, Fe, Mg	+CG

Table A10

SAMPLE 120 xx

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	1	0.12	0.72	✓				X-ray analysis not possible due to close proximity to grid bar	CG
	2	0.05	0.30			✓			
	3	0.02	0.10			✓			
	4	1.25	4.37			✓		Fe, Si	CG
#2	NO FIBERS								
#3	NO FIBERS								
#4	NO FIBERS								
#5	5	0.19	0.43	✓				Mg, Si, Fe	+CG
#6	NO FIBERS								
#7	NO FIBERS								
#8	6	0.12	0.50			✓		Mg, Si, Fe	CG

Table A11

SAMPLE 184 xx

Grid Opening	Fiber No.	Fiber Width, μm	Fiber Length, μm	Diffraction Pattern: Amphibole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambiguous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#1	1	0.31	1.31		✓			S, Ca	
	2	0.19	1.25				✓		
	3	0.25	1.12			✓			
	4	0.31	1.50				✓		
	5	0.31	0.94			✓			
	6	0.25	0.75		✓			S, Ca	
#2	7	0.12	0.37			✓			
	8	0.25	0.94						
	9	0.19	1.25			✓		Mg, Si, Fe	CG
	10	0.31	3.87			✓			
	11	0.31	2.00						
	12	0.19	0.75						
	13	0.31	1.12						
#3	14.	0.50	3.75			✓		Ca only	
	15	0.62	2.37			✓		Mg, Si, Ca, Al	
	16	0.12	0.62			✓		No significant peaks	
	17	0.31	1.25						
	18	0.50	1.88		✓			S, Ca	
#4	19	0.19	0.75						
	20	0.25	1.19						
	21	0.31	1.50						
	22	0.12	0.62						
	23	0.05	0.50				✓		
	24	0.05	0.55				✓		
	25	0.05	0.30				✓		
	26	0.05	0.37				✓		
	27	0.05	0.37				✓		
	28	0.05	0.30				✓		
#5	29	0.25	1.37		✓			No significant peaks	
	30	0.62	3.75		✓			S, Ca only	

Table A12

SAMPLE 186 xx

Grid Opening	Fiber No.	Width, μm	Length, μm	Diffraction Pattern: Amphibole	Non-Amphi.	Ambiguous	Non. cryst.	X-Ray Analysis	Remarks
#1	1	0.31	3.75		✓			Si, Fe, Mg, Ca, Mn, S	
	2	0.19	3.75		✓			Si, Fe, Ca, Mg, S	
	3	0.37	1.25		✓			Si, Fe, Mg	
	4	0.37	2.50		✓			Si, Fe, Mg, Ca	
	5	0.12	1.56			✓		Ca, S	
	6	0.62	1.88	✓				Si, Fe, Ca	+CG
	7	0.12	1.25						
	8	0.19	1.88					Fe, Si, Ca, S, Mg	CG
	9	0.03	0.31		✓				
	10	0.12	1.13			✓		Ca, S	
	11	0.19	1.88			✓		Ca, S, Si, Fe	
	12	0.19	1.25						
	13	0.31	2.50						
	14	0.16	1.13						
	15	0.12	0.81	✓				Si, Fe, Mg, Ca, S, Mn	+CG
	16	0.03	0.31						
	17	0.37	1.25						
	18	0.12	0.62						
	19	0.12	0.62						
	20	0.15	0.62						
	21	0.06	0.75						
	22	0.31	2.81						
	23	0.37	1.25						
	24	0.62	2.50						
	25	0.09	0.50						
	26	0.12	1.00						
	27	0.09	0.94						
	28	0.06	0.62						
	29	0.09	2.50			✓		Ca, S, Mn	
	30	0.15	1.56					Ca, S	
	31	0.62	3.75						
#2	32	1.87	12.50	TOO THICK. MAY BE A BUNDLE				Si, Fe, Mn, Mg	CG
	33	0.19	1.25						
	34	0.15	2.50						
	35	0.06	2.50						
	36	0.25	2.50						
	37	0.15	1.25						
	38	0.06	0.62						
	39	0.06	0.88						

SAMPLE 186 xx (Continued)

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, µm	Length, µm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#2 (cont.)	40	0.12	0.94						
	41	0.06	0.62						
	42	0.06	0.31						
	43	0.25	2.50						
	44	0.12	1.37						
	45	0.50	2.50						
	46	0.25	2.50						
#3	47	0.19	1.76			✓			
	48	0.12	1.25			✓			
	49	0.25	2.50			✓			
	50	0.50	2.50		✓				
	51	0.62	2.50			✓		S, K, Ca	
	52	0.94	5.00						
#4	53	0.62	2.82						
	54	0.31	1.56						
	55	0.62	3.75						
	56	0.43	1.87						
	57	0.19	0.62						
	58	0.19	0.62						
	59	0.25	0.75						

Table A13

SAMPLE 188 xx

Grid Opening	Fiber No.	Fiber Width, µm	Fiber Length, µm	Diffraction Pattern: Amphibole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambiguous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#1	1	0.75	2.50	TOO THICK				Si, Mg, Fe, S, K, Ca	CG
	2	0.25	0.75			✓		Si, Mg, Fe, S, Ca	CG
	3	0.09	0.31			✓		Ca, S	
	4	1.06	5.00	TOO THICK				Ca, S	
	5	1.25	5.00	TOO THICK				Ca, S	
	6	0.19	1.25					Ca, S	
	7	0.12	0.75					Ca, S	
	8	0.07	3.54			✓		Si, Fe, small peaks	
	9	0.19	0.62						
	10	1.00	4.06	TOO THICK				Fe, Si, Mg	CG
	11	0.06	0.37			✓			
	12	0.19	2.50			✓		S, Ca	
	13	0.31	1.56			✓		S, Ca	
	14	0.25	1.56			✓		S, Ca	
	15	0.12	1.88			✓		S, Ca	
	16	0.15	2.50	✓				Mg, Si, Fe	+CG
	17	0.14	6.53	✓				Si, Fe	+CG
	18	0.14	4.32	✓				Si, Fe	+CG
	19	0.31	1.00						
	20	0.19	0.88						
	21	0.06	0.94						
	22	0.12	1.25						
	23	0.12	0.94						
	24	0.07	0.50						
	25	1.88	9.38	TOO THICK				Mg, Si, Fe, Ca, Mn	CG
	26	0.62	8.75			✓		Mg, Si, Fe	CG
	27	1.00	10.00			✓		Mg, Si, Fe	CG
	28	0.06	0.88			✓		Mg, Si, Fe, Ca, K	CG
	29	0.19	0.62						
	30	0.19	0.75						
	31	0.19	2.18			✓		Mg, Si, Fe, Ca, S	CG
#2	32	0.09	1.37	✓				Analysis not possible because of close proximity of grid bar	CG
	33	0.15	1.88	✓					CG
	34	0.31	2.19						
	35	0.15	0.62			✓			
	36	0.06	0.62	✓				Si, Fe	+CG
	37	0.06	0.50	✓				Si, Fe	+CG
	38	0.62	4.06	(POSSIBLE BUNDLE)				Mg, Si, Fe, Ca, K, Mn	CG
	39	0.19	1.37						
	40	0.19	1.00						

SAMPLE 188 xx (Continued)

Grid Opening	Fiber No.	Fiber Width, μm	Fiber Length, μm	Diffraction Pattern: Amphibole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambiguous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#2 (cont.)	41	0.12	0.94						
	42	0.19	0.94						
	43	0.09	0.37						
	44	0.43	3.75			✓		Mg, Si, Fe	CG
	45	0.37	2.62						
	46	0.31	1.25						
	47	0.06	0.31						
	48	0.16	1.17						
	49	0.37	2.34						
	50	0.20	0.94						
	51	0.08	0.31						
	52	0.12	1.56						
	53	0.08	0.62						
	54	0.12	0.39						
	55	0.08	0.31						
	56	0.75	2.81			✓			
#3	57	0.15	0.75					Mg, Si, Fe, S, K, Ca	CG
	58	1.25	3.75	✓				Mg, Si, Fe	+CG
	59	0.19	0.62						
	60	0.31	1.06		✓			Si only	
	61	0.37	1.56			✓			
	62	0.12	0.75						
	63	0.19	0.75						
#4	64	0.75	2.50						
	65	0.06	0.19						
	66	0.06	0.31						
	67	0.09	0.94						
	68	0.03	0.25						
	69	0.12	3.12		✓			Fe only	
	70	0.12	0.50					Fe, Ca only	
	71	0.06	0.31						
	72	0.06	0.88						
	73	0.06	0.31						
	74	1.25	10.00	TOO THICK				Mg, Al, Si, K, Ti, Mn, Fe	CG
	75	0.94	3.75						
	76	0.62	4.69		✓			Mg, Al, Si, K, Ca, Ti, Fe	
	77	0.06	0.19						
	78	0.25	2.25						

Table A14

SAMPLE 190 xx

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	1	0.50	2.81		✓			S, Ca	
	2	0.43	1.75		✓			S, Ca	
	3	0.07	0.30			✓			
	4	0.05	0.55			✓			
	5	0.31	1.37		✓			S, Ca	
	6	0.94	11.30				✓		
	7	0.31	3.12		✓			S, Ca	
#2	8	0.12	4.06				✓		
	9	0.19	1.88				✓		
#3	10	0.50	1.56			✓		Mg, Al, Si, S, Ca, Fe	CG
#4	11	0.08	0.50						
#5	12	0.06	0.50			✓		Al, Si, k, Ca, Fe, Mg	CG
	13	0.19	1.25			✓		Si, Fe, Al, K, Ca, Mg	CG
	14	0.15	0.94			✓		Si, Fe	CG
	15	0.19	2.81		✓			No significant peaks	

Table A15

SAMPLE 199 xx Blank

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	1	0.06	1.12				✓		
	2	0.03	0.62				✓		
	3	0.03	0.31				✓		
	4	0.06	0.75				✓		
	5	0.03	0.62				✓		
	6	0.94	2.19	✓					Not a fiber*
#2	7	0.02	0.50			✓			
	8	0.02	0.19			✓			
#3	9	0.09	0.62						
#4	NO FIBERS								
#5	NO FIBERS								
#6	10	0.06	0.62		✓				
#7	NO FIBERS								

* This particle may be discounted since length/width ratio is less than 3.

Table A16

SAMPLE 200 xx

Grid Opening	Fiber No.	Width, µm	Length, µm	Diffraction Pattern: Amphibole	Non-Amphi.	Ambiguous	Non. cryst.	X-Ray Analysis	Remarks
#1	1	0.94	2.81	✓				Mg, Si, Ca, Fe	+CG
	2	0.19	0.94			✓		Si, S, Ca, Fe	CG
#2	3	0.19	0.94			✓		Fe only	
	4	0.06	0.94			✓		Fe only	
	5	0.31	1.25	✓				Mg, Si, Fe	+CG
	6	0.37	1.25	✓				Mg, Si, Fe	+CG
	7	0.19	0.62	✓				Mg, Si, Fe	+CG
#3	NO FIBERS								
#4	8	0.19	1.25			✓		Si, Fe	CG
	9	0.62	3.75		✓			Mg, Si, Ca, Fe	
	10	1.25	7.50			✓		Fe only	
#5	11	0.19	1.12			✓		S, Ca	
	12	0.19	1.25			✓		Al, Si, S, Ca, Fe	CG
	13	0.12	0.50			✓		S, Ca	
	14	0.12	0.56			✓		S, Ca	
	15	0.12	0.37		✓			S, Ca	
#6	16	0.06	0.50						
	17	0.09	0.75		✓				
	18	0.09	0.62						
	19	0.37	1.12						
	20	0.09	0.62						
	21	0.12	1.25		✓				
	22	0.12	1.12		✓				
	23	0.12	0.94		✓				
	24	0.15	1.25		✓				
	25	0.12	1.88		✓				
	26	0.09	0.62		✓				
	27	0.09	0.50		✓				
	28	0.12	1.25		✓				
	29	0.12	0.94		✓				
	30	0.09	0.62		✓				
#7	31	0.19	0.62		✓				
#8	32	0.15	0.62						
	33	0.19	0.94						
	34	0.19	2.50						
	35	0.15	0.50						

SAMPLE 200 xx (Continued)

Grid Opening	Fiber No.	Fiber Width, µm	Fiber Length, µm	Diffraction Pattern: Amphibole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambiguous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#8	36	0.06	0.25		✓				
(cont.)	37	0.12	0.75		✓				
#9	38	0.03	0.19			✓			
	39	0.06	0.19			✓			
	40	0.06	0.50			✓			
	41	0.06	1.56						
	42	0.12	1.25						
	43	0.06	0.50						
	44	0.06	0.37						
#10	45	0.12	1.00			✓			
#11	46	0.03	0.19				✓		
	47	0.03	0.50						
	48	0.12	0.75						
	49	0.06	1.25	✓					CG
	50	0.06	0.62	✓					CG
	51	0.12	0.75						
	52	0.06	1.56						
	53	0.06	0.62						
	54	0.06	0.31						

Table A17

SAMPLE 222 xx

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	1	0.03	0.25				✓		
	2	0.03	0.75				✓		
	3	0.03	0.31						
	4	0.12	1.25		✓			No peaks in the analysis	
	5	0.06	0.62		✓			No peaks in the analysis	
	6	0.07	0.62		✓			No significant peaks	
	7	0.03	0.31		✓			No significant peaks	
#2	NO FIBERS								
#3	8	0.05	0.22		✓			No significant peaks	
#4	NO FIBERS								
#5	9	0.05	0.31					No significant peaks	
#6	NO FIBERS								

Table A18

SAMPLE 236 xx

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, µm	Length, µm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	NO FIBERS								
#2	NO FIBERS								
#3	1	0.02	0.31				✓		
	2	0.02	0.12			✓			
	3	0.05	0.37		✓			No significant peaks	
	4	0.08	0.45		✓			No significant peaks	
	5	0.05	0.25		✓			No significant peaks	
	6	0.05	0.37		✓			No significant peaks	
	7	0.20	0.62					No significant peaks	
#4	8	0.05	0.25				✓		
#5	NO FIBERS								
#6	9	0.25	0.87		✓			No significant peaks	
#7	10	0.31	1.44			✓		No significant peaks	

Table A19

SAMPLE 250 xx

Grid Opening	Fiber No.	Fiber Width, µm	Fiber Length, µm	Diffraction Pattern: Amphibole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambiguous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#1	1	0.12	0.50			✓		No significant peaks	
	2	0.12	0.37						
	3	0.06	0.50						
	4	0.19	0.62						
	5	0.19	0.75			✓			
	6	0.28	5.29	✓				Mg, Si, S, Fe	+CG
	7	0.24	1.92	✓				Mg, Si, Fe	+CG
	8	0.24	1.92			✓		Mg, Si, S, Fe	CG
	9	0.24	1.73			✓		Mg, Si, S, Fe,	CG
	10	0.19	1.12			✓		S,	
	11	0.12	0.94			✓		Si, Fe	CG
	12	0.12	0.62						
	13	0.19	0.75						
	14	0.43	1.88		✓			Ca, S	
	15	0.31	3.75			✓		Ca, S, Fe	
	16	0.25	1.00			✓		Ca, S	
	17	0.31	2.50			✓		Ca, S	
	18	0.12	1.88			✓		Ca, S	
	19	0.12	3.13			✓		Ca, S, Fe, Si	
#2	20	0.06	0.62						
	21	0.12	0.62						
	22	0.12	0.75						
	23	0.06	0.31						
	24	0.06	0.75						
	25	0.09	0.94						
	26	0.12	0.37						
	27	0.19	0.62						
	28	0.37	1.25			✓		S, Ca,	
	29	0.03	0.12						
	30	0.06	0.25						
	31	0.06	0.25						
	32	0.06	0.37						
#3	33	0.06	0.25						
	34	0.12	0.62						
	35	0.03	0.31						
	36	0.06	0.62						
	37	0.12	0.94						
	38	0.16	1.00						
	39	0.19	0.75			✓		S, Ca	
	40	0.09	0.62				✓	S, Ca	
	41	0.06	0.25						

SAMPLE 250 xx (Continued)

Grid Opening	Fiber No.	Fiber Width, µm	Fiber Length, µm	Diffraction Pattern: Amphibole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambiguous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#3	42	0.31	1.38			✓		S, Ca	
(cont.)	43	0.50	1.56				✓		
	44	0.19	1.88				✓	Ca, S	
	45	0.07	0.37						
	46	0.15	1.25			✓		S only	
	47	0.06	0.62						
	48	0.03	0.62						
#4	49	0.09	0.62						
	50	0.12	0.75						
	51	0.12	0.75						
	52	0.19	0.62						
	53	0.15	0.62						
	54	0.12	0.50						
	55	0.06	0.75						
	56	0.07	0.87			✓		Si, Cl	
	57	0.19	0.75						
	58	0.06	0.62			✓		P, S only	
	59	0.06	0.50			✓		P, S only	
	60	0.12	0.62						
	61	0.94	7.50	TOO THICK				Ca, S	
	62	0.12	0.94						

Table A20

SAMPLE 305 xx Blank

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	NO FIBERS								
#2	NO FIBERS								
#3	NO FIBERS								
#4	1	0.06	0.19			✓		No significant peaks	
	2	0.03	0.12			✓		No significant peaks	
#5	3	0.19	0.62		✓			Fe only	
	4	0.03	0.25		✓			Fe only	
	5	0.03	0.25		✓			Fe only	
	6	0.12	0.37		✓			Fe only	
	7	0.12	0.75		✓			Fe only	
#6	NO FIBERS								

Table A21

SAMPLE 306 xx

Grid Opening	Fiber No.	Fiber Width, μm	Fiber Length, μm	Diffraction Pattern: Amphibole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambiguous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#1	1	0.43	3.12	✓				Mg, Si, Fe	+CG
	2	0.50	1.88			✓		Mg, Si, Mn, Fe	CG
	3	0.62	2.18	✓				Mg, Si, Mn, Fe	+CG
	4	1.00	3.12	✓				Mg, Si, Fe	+CG
#2	5	0.06	0.75		✓				
	6	0.19	0.62		✓				
	7	0.31	0.94	✓				Mg, Si, Fe	+CG
#3	8	0.31	1.75						
	9	0.25	0.75						
	10	0.19	0.75						
	11	1.00	6.00	✓				Mg, Si, Fe	+CG
	12	0.50	1.88						
	13	0.25	1.56						
	14	0.31	2.25						
#4	15	0.31	1.25	✓					CG
	16	0.31	2.82						
	17	0.50	1.56	✓					CG
	18	0.06	1.13			✓			
	19	0.31	0.94						
	20	0.12	0.56	✓					CG
	21	0.62	1.88						
	22	0.12	0.62						
	23	0.06	0.75						

Table A22

SAMPLE 308 xx

Grid Opening	Fiber No.	Fiber Width, μm	Fiber Length, μm	Diffraction Pattern: Amphibole	Diffraction Pattern: Non-Amphi.	Diffraction Pattern: Ambiguous	Diffraction Pattern: Non. cryst.	X-Ray Analysis	Remarks
#1	1	0.06	0.25			✓		Si, Fe, Mg	CG
	2	0.05	0.20			✓		Si, Fe	CG
#2	3	A BUNDLE			✓			No significant peaks	
	4	TWO GROUPS			✓			No significant peaks	
#3	5	0.19	0.94	✓				Si, Fe, Ca, Mg	+CG
	6	0.19	0.94	✓				Si, Fe	+CG
	7	0.09	0.31			✓		No significant peaks	
	8	0.62	2.00			✓		Si, Fe, Mg	CG
#4	9	0.31	2.82			✓		No significant peaks	
	10	0.94	2.94			✓		No significant peaks	
	11	0.05	0.15			✓		No significant peaks	
	12	0.07	0.30			✓		No significant peaks	
	13	0.07	0.30			✓		No significant peaks	
	14	0.07	0.50			✓		No significant peaks	
	15	0.50	1.50						
	16	0.31	1.88			✓		No significant peaks	
	17	0.31	1.88			✓		No significant peaks	
	18	0.25	0.94						
	19	0.50	1.44						
#5	20	0.07	0.30						
	21	0.07	0.25						
	22	0.05	0.25						
	23	0.07	0.45						
	24	0.31	0.94			✓		No significant peaks	
	25	0.37	1.50						

Table A23

SAMPLE 310 xx

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	1	0.31	3.44				✓		
	2	0.19	2.19				✓		
	3	0.50	1.88	✓				Mg, Si, Mn, Fe	+CG
	4	0.31	1.06	✓				Mg, Si, Fe	+CG
	5	0.25	1.43	✓				Mg, Si, Fe	+CG
	6	0.31	1.31	✓				Mg, Si, Fe	+CG
	7	0.25	0.94	✓				Si	
#2	8	0.50	1.50	✓				Mg, Si, Ca, Fe	+CG
#3	9	0.12	1.37				✓		
#4	10	0.62	1.87			✓		Mg, Si, Fe	CG
#5	11	0.19	0.81				✓		
#6	12	0.19	1.56				✓		

Table A24

SAMPLE 312 xx

Grid Opening	Fiber			Diffraction Pattern				X-Ray Analysis	Remarks
	Fiber No.	Width, μm	Length, μm	Amphi-bole	Non-Amphi.	Ambi-guous	Non. cryst.		
#1	1	0.06	1.25		✓			Ca, S	
	2	0.06	0.37		✓			Ca, S	
	3	0.06	0.31		✓			Ca, S	
	4	0.06	0.31		✓			Fe only	
#2	5	0.06	0.25			✓			
	6	0.15	0.75		✓			Ca, S	
#3	7	0.25	1.25						
	8	0.62	2.25	✓				Mg, Si, Fe	+CG
	9	0.12	0.75	✓				Mg, Si, Fe	+CG
	10	0.62	2.50			✓		Mg, Si, Ca, Fe	CG
	11	0.62	2.19		✓			Fe only	
	12	0.94	3.43		✓			Fe only	
	13	0.06	0.31		✓			Fe, Si	
	14	0.12	0.94			✓		Ca, S	
	15	0.09	0.37			✓		Ca, S	
	16	0.06	0.75						
	17	0.06	0.31						
	18	0.06	0.94			✓		No significant peaks	
	19	0.06	0.25			✓		No significant peaks	
#4	20	0.09	0.94				✓		
	21	0.81	2.81	TOO THICK					
	22	0.12	0.37	✓					CG
#5	23	0.31	0.94	✓					CG
	24	0.09	0.62	✓					CG
	25	0.19	1.56			✓			
	26	0.15	1.25			✓			
	27	0.22	1.87	✓					CG
#6	28	0.94	2.81	(POSSIBLE BUNCH) NON-AMPHIBOLE					
	29	0.06	0.50						
	30	0.03	0.19						
	31	0.03	0.12						
	32	0.12	0.62						
#7	33	0.75	3.75	✓					CG
	34	0.94	3.12	✓					CG

APPENDIX B

CHEMICAL SYMBOLS AND ELEMENTS

Table B1

CHEMICAL SYMBOLS AND ELEMENTS

Symbol	Element
Al	Aluminum
Ca	Calcium
Fe	Iron
K	Potassium
Mg	Magnesium
Mn	Manganese
S	Sulfur
Si	Silicon
Ti	Titanium

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